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EVALUATION OF FOUR INERT DUSTS FOR THE PROTECTION OF SHELLED CORN IN GEORGIA FROM INSECT ATTACK

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Insects mentioned in this publication

Almond moth	*Cadra cautella* (Walker)
Angoumois grain moth	*Sitotroga cerealella* (Oliv.)
Cadelle	*Tenebroides mauritanicus* (L.)
Confused flour beetle	*Tribolium confusum* Jacquelin duVal
Dermestid larva	*Trogoderma parabile* Beal
Flat grain beetle	*Cryptolestes pusillus* (Schönherr)
Granary weevil	*Sitophilus granarius* (L.)
Indian-meal moth	*Plodia interpunctella* (Hbn.)
Lesser grain borer	*Rhyzopertha dominica* (F.)
Red flour beetle	*Tribolium castaneum* (Herbst)
Rice weevil	*Sitophilus oryzae* (L.)
Saw-toothed grain beetle	*Oryzaephilus surinamensis* (L.)

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EVALUATION OF FOUR INERT DUSTS FOR THE PROTECTION OF SHELLED CORN IN GEORGIA FROM INSECT ATTACK

By L. M. Redlinger and H. Womack[1]

SUMMARY

Two diatomaceous earths--Kenite® and Perma-Guard®--were applied at the rate of 7 pounds per ton of shelled corn, and two silica aerogels--Dri-Die® SG-68 and Cab-O-Sil® M-5--were applied at the rate of 1 pound per ton. These inert dusts were compared with malathion for the protection of shelled corn from insect attack. An emulsifiable concentrate of 57-percent premium-grade malathion used as the standard treated check was applied at the rate of 1 pint per 1,000 bushels of corn. All treatments and the untreated checks were replicated five times. Metal, 500-bushel bins were used as grain containers. This progress report presents data for the first year of a 2-year experiment.[2]

Commercial grades on corn samples were lowered by treatment with the inert dusts. Test weight was lowered an average of 3.7 pounds per bushel on corn treated with diatomaceous earth and 2.6 pounds per bushel on corn treated with silica aerogel. The test weight of the untreated and malathion-treated corn was almost unchanged.

Dust treatments reduced the loading capacity of the grain conveyor to one-half its capacity for untreated or malathion-treated shelled corn. Dust-treated corn was packed and very difficult to probe for samples.

The overall moisture content of the corn decreased slightly during the year's storage.

Residues on malathion-treated corn averaged 9.9 p.p.m. immediately after treatment and decreased to 2.9 p.p.m. by the end of the year.

All treatments reduced the initial insect infestation to a very low level in the corn. The number of insects in the untreated check corn, however, continued to increase, and by the second month of storage, this corn was "weevily" according to official Grain Standards of the United States.

SG-68 and malathion were the most effective in keeping insect populations from developing in the corn. Perma-Guard, Kenite, and Cab-O-Sil lost much of their effectiveness after 9 months of storage, as evidenced by increases in numbers of live insects, development of insect progeny, and insect-damaged kernels. One bin of corn treated with Cab-O-Sil was "weevily" after 1 year's storage. Perma-Guard provided the shortest residual protection. One bin became "weevily" at 11 months and two more bins at 12 months.

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[1] Entomologists, Market Quality Research Division, Agricultural Research Service, Tifton, Ga.

[2] Residue and X-ray analyses were performed at the USDA Stored-Product Insects Research and Development Laboratory at Savannah, Ga. Tests of repellency of treated corn to insects were performed at the USDA Mid-West Grain Insects Investigations unit at Manhattan, Kans. Aklee Cagle, agricultural research aid, and W. O. Farmer and Huey Hall, biological laboratory technicians, assisted in many phases of these experiments. Development and analyses of radiographs were done by Robert L. Kirkpatrick, research entomologist.

The toxicity of all insecticides tested decreased as the length of storage increased. None of the dusts were as effective as malathion. Of the four inert dust treatments, Kenite was one of the most effective against rice weevils, red flour beetles, and confused flour beetles.

Resistance to inert dusts differed among the various insect species, as well as among the several stages within species. Rice weevils and red flour beetles were more susceptible than confused flour beetles to inert dusts.

In bioassays, corn treated with inert dusts showed a high degree of repellency to rice weevils when compared with the repellency of untreated corn.

BACKGROUND AND PURPOSE OF WORK

For many years agricultural researchers have evaluated inert dusts that are used as protectants for stored grain. Interest in the use of inert dust for the prevention or control of insect infestation in stored products is renewed periodically.

Carlson and Ball (2)[3] made a comprehensive review of the literature on inert dust. Their review mentioned some of the insect species that have been killed by inert dust and the mode of action of the dust. They also presented data on dosage-mortality curves for eight species of stored-grain insects. Ranking in order of decreasing susceptibility, these species were: Flat grain beetle, rice weevil, granary weevil, lesser grain borer, saw-toothed grain beetle, dermestid larva, red flour beetle, and confused flour beetle.

Carlson and Ball further reported that dosage rates of 5 and 6 pounds of diatomaceous earth per ton were effective against the flat grain beetle, but that mortality of the remaining species did not approach the criterion for commercial kill.

Considerable variation occurs in the order of susceptibility of a series of insects to a given group of dusts. Researchers have reported effectiveness of inert dust ranging from complete control to very poor control. The degree of effectiveness depended upon particle size and shape, hardness, concentration, relative humidity, temperature, grain moisture, and other factors (1, 3, 7, 10).

Several of these investigators showed that the relative humidity of the environment was an important factor influencing the toxicity of inert dust. Insect mortality was obtained much more quickly at low relative humidities than at high relative humidities. However, Alexander et al. (1) demonstrated that the highly effective dusts still have very pronounced action when relative humidities are as high as 95 percent.

Most of the information available on the use of inert dust as a grain protectant has been limited to laboratory experiments. Strong and Sbur (9) tested a diatomaceous earth for preventing and controlling insect infestations in wheat. They reported that an application rate of 6 pounds of dust per ton of grain protected it for 9 months, and 8 pounds per ton was still effective at 12 months. However, the data showed about 100 insects per 2,000-gram sample of grain at the end of 12 months with the 8-pound dosage rate.

Very few accounts have been published of large-scale experiments using inert dust as a grain protectant. Cotton and Frankenfeld (4) reported on one large-scale test in which an inert dust failed to prevent infestation when used on wheat with a moisture content of 12.2 percent. These scientists concluded that conditions in the bulk grain did not allow rapid evaporation of body moisture from the insects.

Large-scale use of inert dust has never been widely accepted by the grain industry. Some main factors that restrict the use of inert dust with grain are: (1) Limitations on the free-running properties of grain, (2) reductions in test weight per bushel, (3) excessive dust in the atmosphere during handling, and (4) difficulty in assessing grain quality.

In the past, grain containing noticeable amounts of diatomaceous earth was graded "DLQ" (Distinctly Low Quality). Recent changes in the commercial grain grading standards allow such grain to be graded as if the diatomaceous earth were not present, provided approved laboratory tests show that the grain does not contain any other foreign substance.

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[3] Underlined numbers in parentheses refer to Literature Cited.

The present study covers large-scale field experiments designed to evaluate the effectiveness of diatomaceous earth dusts--Kenite® and Perma-Guard®--and silica aerogels--Dri-Die® SG-68 and Cab-O-Sil® M-5--in controlling an initial infestation in grain and in preventing reinfestation of grain under various climatic conditions. Malathion was used as a standard treatment check.

Beginning in the fall of 1963, field experiments were conducted concurrently with shelled corn at Watseka, Ill., and Tifton, Ga., and with wheat at McPherson, Kans. The same general procedure was used at all three locations in order that results would be comparable. Experimental results obtained at Watseka and McPherson have been reported separately (8, 11).

The Tifton experiment was started September 17, 1963, and the last bin was treated October 2, 1963. This publication reports the results at Tifton, Ga., at the end of the first 12 months of study. Final results will be published at the conclusion of the 2-year study.

EXPERIMENTAL MATERIALS AND PROCEDURE

Bins

Standard circular metal bins 11 feet in height, 10 feet in diameter, and with a capacity of 500 bushels were used in the study.

An aeration system was installed in each bin before it was loaded with corn. A vertical air duct 8 inches in diameter and fabricated in 3-foot sections of 22-gage steel was hung with chains from the roof opening. The bottom 3-foot section of the duct was perforated. Another 6 feet of nonperforated duct extended to the top of the bin above the corn level. The lower end of the duct was fastened to the floor to prevent movement when the corn was loaded into the bins. A 12-quart pail was suspended above the duct opening during loading to prevent corn and dust from entering the duct. The conveyor discharge spout was centered over the pail, which helped to scatter the corn and distribute dockage throughout the corn mass. Figure 1 shows the distribution of corn during load-in of a bin. After the bins were filled and leveled, the 12-quart pail was removed. An electric fan, rated at a capacity of 100 c.f.m., was then installed on top of the duct.

Electrical wiring at the binsite was not completed until March 11, 1964. Therefore, the bins were not aerated during the first $5\frac{1}{2}$ months of storage.

The aeration controls were set to aerate the corn whenever the temperature dropped below 58° F. and the relative humidity was above 65 percent. The high humidity setting was used to prevent a reduction in moisture content of the corn. Under these conditions, the corn was aerated 134 hours in March, 69 hours in April, and 13 hours in May 1964.

The temperature of the corn in September ranged from 80° to 85° F., according to determinations made of samples from trucks at the time of treatment. Corn temperature in bins was not recorded until December. From the third month until the ninth month of storage, corn temperatures were recorded monthly in each bin with a deep-bin thermometer that was pushed into the shelled corn near the center of the corn mass. After all probe samples had been drawn, the thermometer was removed and the temperature recorded.

Thermocouple cables were installed in each bin in June, the ninth month of storage. These cables were 11 feet long, had four junction points for temperature readings, and were inserted in the shelled corn near the center of the bin about 2 feet from the vertical aeration duct. Thermocouple junction points for recording temperature were located at 1 foot, 4 feet, and 7 feet above the bin floor, and at the surface of the corn. Temperatures were read with a direct-reading potentiometer equipped with a 4-position switch.

Bin thermometer temperature readings were discontinued after potentiometer readings were started in June. Both methods were used during June, however, for comparison.

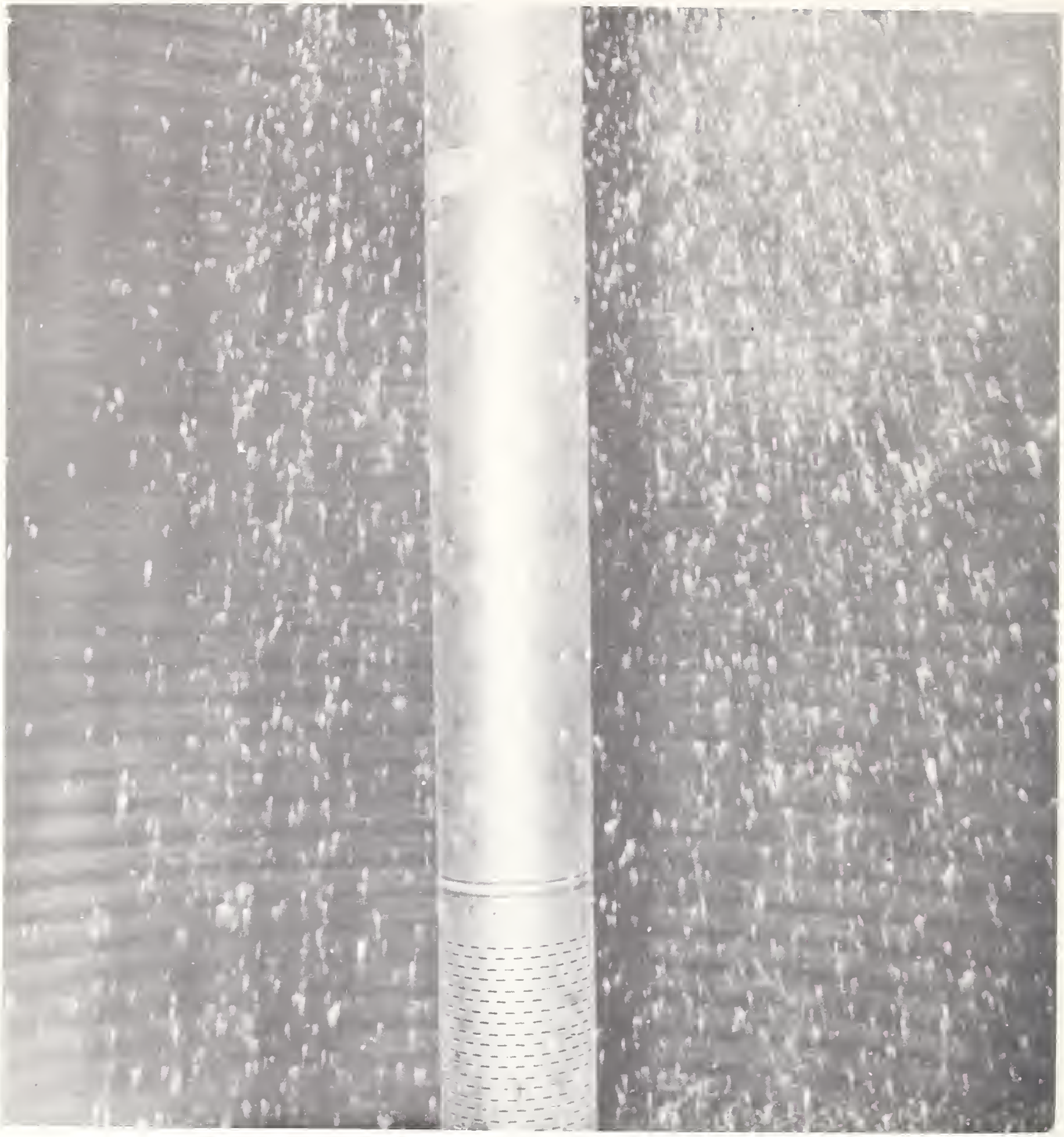

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Figure 1.--Interior of corn bin, showing central aeration duct and horizontal distribution of corn as it falls into bin.

Corn

To provide uniform corn for the tests at both Watseka and Tifton, a warehouse at Gilman, Ill., handled and blended the total corn required for both stations. Illinois corn from the 1962 crop was shelled on the farm and trucked by the producer to the elevator. Corn from the various farms was mixed at the elevator for uniformity. Approximately 15,000 bushels were shipped by rail to Tifton, Ga., and by truck to the binsite at the Georgia Coastal Plain Experiment Station.

The corn was unloaded into the bins from the trucks with a portable screw conveyor 6 inches in diameter, 32 feet long, and powered with a gasoline engine. Probe samples from each truck were composited for each bin. A representative 2,000-gram sample, sealed in a plastic-lined cloth bag, was forwarded for grading to the Kansas City District Office of the Grain Division, Consumer and Marketing Service, U.S. Department of Agriculture. Similar samples were drawn from each bin immediately after treatment and again at the end of 12 months' of storage.

Moisture content was determined on each probe sample of shelled corn drawn from the bins at monthly intervals.

During the first 3 months, a Steinlite moisture meter was used. After December, the moisture content was determined with a Motomco meter. The Steinlite meter read approximately 1 percent low, based on the official moisture readings of grade samples. After the moisture was recorded, the grain sample was immediately returned to the jar for other tests.

Insects

The following species of insects were reared at the ARS Tifton laboratory and used in these experiments: Rice weevils at two stages--as adults 4 weeks after emerging from corn and as larvae 21 to 24 days old; confused flour beetles as adults 4 weeks old; and red flour beetles as adults 4 weeks old. The insect culture room was maintained at $80^{\circ} \pm 2^{\circ}$ F. and 60 ± 3 percent relative humidity.

The rice weevils were reared on locally grown Coker 71 corn to which about 5 percent brewers' yeast had been added. The moisture content of this corn was tempered to 14.5 percent before infestation. The flour beetles were reared on a mixture of 47.5 percent wheat flour and yellow cornmeal to which 5 percent brewers' yeast had been added.

All corn was artificially infested immediately before dust or other treatment was applied. Before the Illinois corn was received, some 1962-crop corn was purchased from a local warehouse in which it had been stored as snapped corn in a wire-enclosed, open crib from harvest. This corn was shelled and held in small fiberboard drums, each of which had a capacity of about 100 pounds. The corn had developed a natural infestation of stored-grain insects. In addition to this natural infestation, 300 adult rice weevils were released at 10-day intervals into each 100-pound container of corn.

One day before the large-scale experiment was started, all the local corn was blended together to provide a uniform mixture of infested corn for each bin in the test.

A composited sample of the infested corn for each of the 30 bins was reduced to a representative 333-gram sample, which was held in the laboratory and screened weekly for 6 weeks. The number of insects that emerged was recorded for each sample. Adult insects were recorded and discarded at each examination, and all screenings were returned to the sample. The average number of insects per 1,000 grams of corn was: 419 rice weevils, 2 lesser grain borers, 106 red flour beetles, 74 flat grain beetles, 2 saw-toothed grain beetles, 1 cadelle, 16 Angoumois grain moths, 7 Indian-meal moths, and 5 almond moths.

In addition to the natural infestation already described, the following were also added to the corn for each bin: 2,000 rice weevils, 2,000 red flour beetles, 1,000 saw-toothed grain beetles, 1,000 flat grain beetles, and 10 cadelles. A potential total of more than 16,500 insects was added to each bin. All infested corn and adult insects were added in a uniform manner to each truck of test corn as it was being unloaded.

TABLE 1.--Comparison of characteristics of inert dusts used with shelled corn at Tifton, Ga., September 1963 - September 1964

Characteristic	Unit	Diatomaceous earth		Silica aerogel	
		Perma-Guard	Kenite	Dri-Die SG-68	Cab-O-Sil M-5
Moisture.........	Percent	1.5-3.0	8.0	4.0	0.2-1.5
Dry density......	Lb./cu. ft.	20.0-24.0	14-15	[1] 5.0	[2] 2.5-3.5
Mesh............	Percent retained on 325 mesh.	9.0-13.0	[3] <10	--	--
Particle size....	Microns	0.1-40.0	--	[4] 3.5	0.015-0.020
Silica...........	Percent SiO_2	80.0 (minimum)	88.0	99.0+	99.0-99.7
Cristobalite.....	Percent (maximum)	1.0	--	--	--
Surface area.....	$Cm.^2$/gram	20,000-30,000	30,000	[5] 300	[5] 175-200
Hydrogen-ion concentration.....	pH	--	7.0	7.4	3.5-4.0
Brightness or color..........	Photovolt	60-75	70	White	White
Refractive index..	--	--	--	1.46	1.55
Specific gravity.	--	--	--	2.1	2.1
Bulking value....	Gal./lb.	--	--	--	0.057

[1] Bulk density.
[2] Bulk density, fluffy grade; dense grade, 6.5-7.0.
[3] On 200 mesh, less than 3 percent.
[4] Average; 80 percent is less than 5.5 microns.
[5] Square meters per gram.

Treatments

Two diatomaceous earths (Kenite® and Perma-Guard®) and two silica aerogels (Cab-O-Sil® M-5 and Dri-Die® SG-68) were used in the tests. These inert dusts were purchased on the open market from four manufacturers. The characteristics of the dusts, as supplied by the various manufacturers, are presented in table 1. The cost (f.o.b. Tifton) of the dusts in cents per bushel of corn was as follows: Dri-Die SG-68, 3.0; Cab-O-Sil M-5, 2.3: Perma-Guard, 2.2; Kenite, 1.7; and malathion, 0.1.

The treatments were replicated five times for each inert dust. Dusts were applied according to manufacturer's recommendations--7 pounds per ton for diatomaceous earth and 1 pound per ton for silica aerogel. As a standard for comparison, five bins were treated with an emulsifiable concentrate of 57-percent premium-grade malathion at the rate of 1 pint per 1,000 bushels of grain. In addition, five bins were left untreated as checks.

The dust was applied by an automatic forced-feed dust applicator as the shelled corn fell from the trucks into the conveyor hopper (figs. 2, 3). It was expected that the dust would be

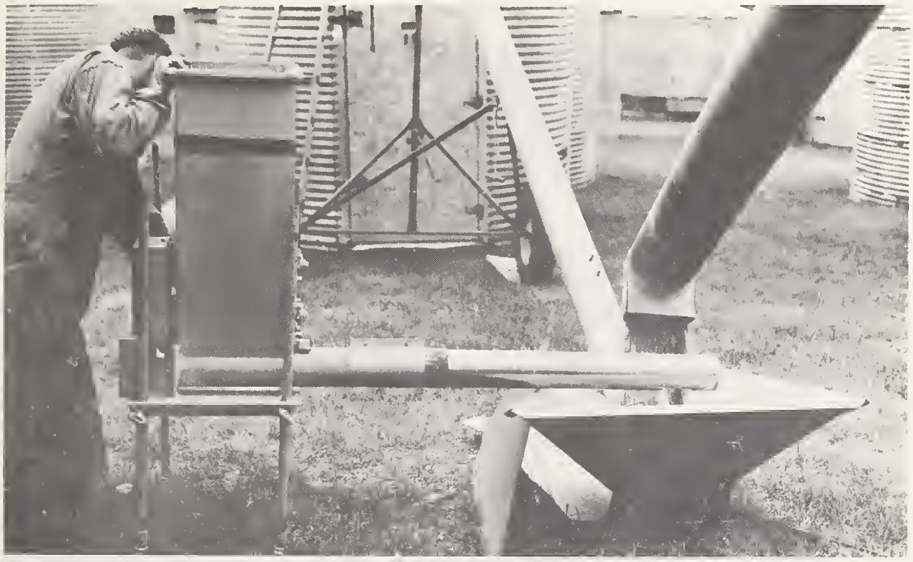

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Figure 2.--View of applicator used in applying inert dust to shelled corn during load-in operation.

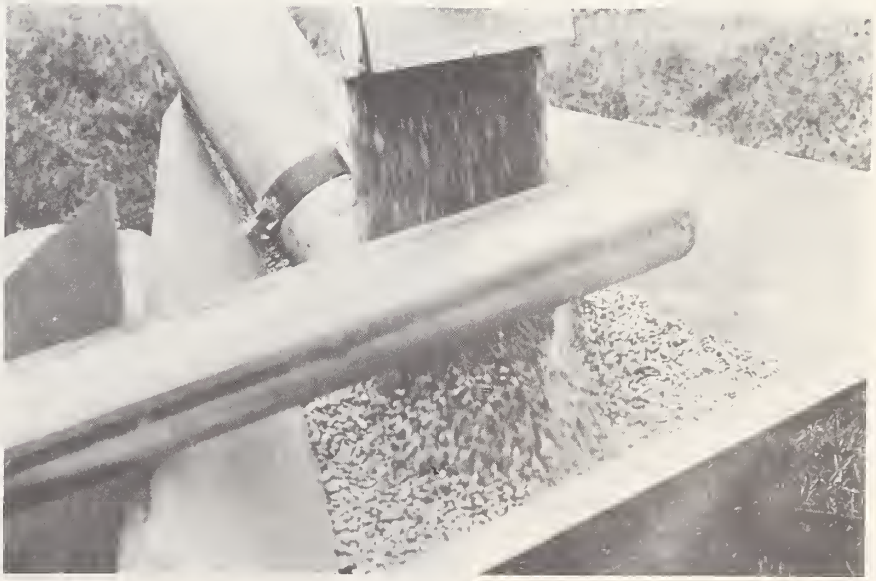

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Figure 3.--Close-up of applicator discharge spout showing a constant flow of inert dust into the conveyor hopper.

thoroughly distributed as the corn passed through the screw conveyor and cascaded into the bins. To prevent overloading the conveyor and motor, it was necessary to regulate the flow of shelled corn treated with inert dust. The dust treatments reduced the loading capacity of the conveyor to one-half that for the untreated or malathion-treated shelled corn.

Malathion was applied by an electrically driven gear pump. A fan-shaped spray nozzle was calibrated to apply the required amount of spray to the corn in the conveyor hopper at the same location that dust was applied.

The five untreated check bins were filled first to avoid contaminating this corn from the conveying equipment. Applications were completed for each treatment series of five replications before the next treatment was started, and all equipment was thoroughly cleaned between treatments. During treatment, the wind was deflected from the point of application of spray and dust to minimize drift and loss of insecticides. A small piece of canvas was wrapped around the conveyor discharge spout to seal off the top bin hatch during load-in.

A comparison of the various treatments on representative samples of shelled corn is shown in figure 4. The dust can be readily seen on the kernels of corn, especially those treated with Kenite and Perma-Guard.

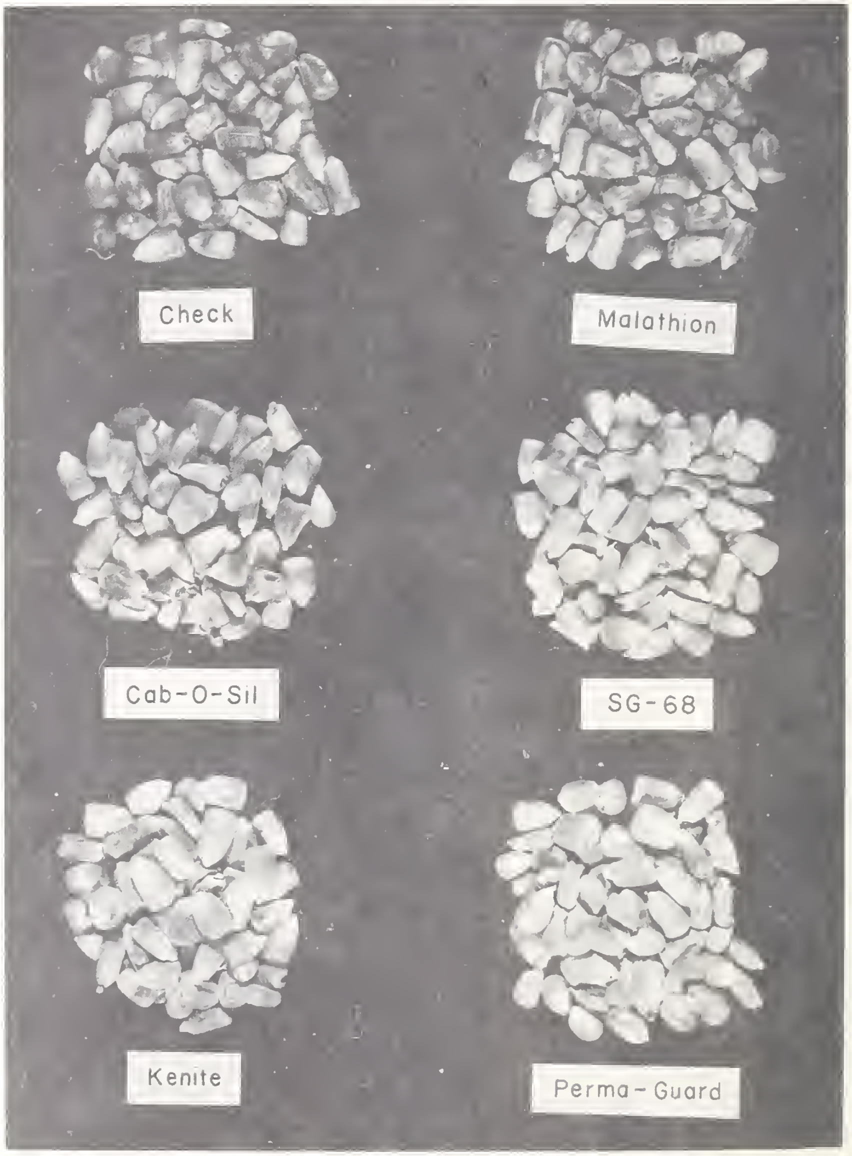

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Figure 4.--Representative samples of shelled corn that has been treated with malathion and four inert dusts. Note heavy deposits of dust visible on corn treated with Kenite and Perma-Guard.

Sampling

In order to minimize the effect of position, all treatments were randomized at the binsite. Samples were drawn before treatment, immediately after treatment, and at monthly intervals to determine species and abundance of insects, moisture content, damage, and other factors related to the physical condition of the corn. The pretreatment samples were taken from each truck with a regulation grain trier, according to standard grain grading methods. Samples taken after treatment were obtained by probing the bins at 10 locations. Separate sets of samples were drawn from the bins for each of the major determinations--grade, insects, and bioassays. Samples were drawn from top and bottom depths in the four quadrants and the center of each bin, using a 5-foot, 11-compartmented, deep bin trier. Since headspace between the bin roof and the corn surface was limited, samples were drawn from the center roof hatch. The trier was angled from the center of the bin to the outside wall for all bottom samples.

Probe samples, for checking numbers and species of insects, were placed in separate 1-quart jars and taken to the laboratory for examination. The samples for grade were composited for each bin, thoroughly mixed, and then reduced with a grain divider to 2,000 grams.

At 1 month and every 3 months after treatment, bioassays were conducted to determine the residual toxicity of the treatments. Four samples, 175 grams each, were divided from the 10 composited probe samples from each bin. Each sample was placed in a 1-pint jar and covered with a 40-mesh bronze wire top. The jars were held in a room maintained at 80° ± 2° F. and 60 ± 3 percent relative humidity. Fifty 4-week-old adult confused flour beetles, red flour beetles, or rice weevils were confined in each of three of the jars from each bin. Fifteen grams of corn infested with 3½-week-old rice weevil larvae were added to the fourth jar of corn, which was then slowly tumbled to mix the corn thoroughly.

The first three samples from each bin, those to which the three kinds of adult insects had been added, were examined at the end of 21 days. Each sample was screened to separate the insects from the corn. The number and species of live and dead insects in each sample were recorded. Insects that did not respond to gentle prodding when examined were counted as "dead." In most cases, the appearance was characteristic; and only a small proportion needed careful examination. All screenings were returned to the original sample after the insects were removed. These samples were reexamined 42 days later, and the number and mortality of progeny were recorded.

In the fourth sample from each bin, using the immature stage of the rice weevil, the number and mortality of progeny were recorded from examinations made at the end of 56 days.

The repellency of representative samples of shelled corn from the various treatments was tested at 1 month and every 3 months after treatment. Samples were shipped in plastic-lined cloth bags to the Mid-West Grain Insects Investigations laboratory at Manhattan, Kans., for testing. Untreated corn from the five check bins was paired with the treated corn in the repellency testing apparatus.

The repellency testing apparatus described by Laudani and Swank (6), with some modifications by Berndt[4], was used for these experiments. Figures 5 and 6 show the modified apparatus.

Cups of treated and untreated corn were alternated around a central arena in the repellency testing apparatus. Five hundred 1- to 2-week-old adult rice weevils, reared from wheat, were liberated in the center of the chamber. The rice weevils were free to enter the cups of their selection. After 24 hours, the cups of corn were removed from the chambers and immediately covered with a lid so that no weevils could escape. The rice weevils were sifted from the corn in each container, counted, and the number recorded. Calculations for determining percent repellency are described by Laudani, Davis, and Swank (5).

The samples were maintained and the tests were conducted at 80° ± 2° F. and 60 ± 3 percent relative humidity. No moisture adjustments were made on any of the test corn.

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[4] Berndt, Wayne L. Synergism in the repellent action of combinations of piperonyl butoxide and allethrin. Unpublished Ph. D. thesis, Kansas State University, Manhattan, Kans. 1963.

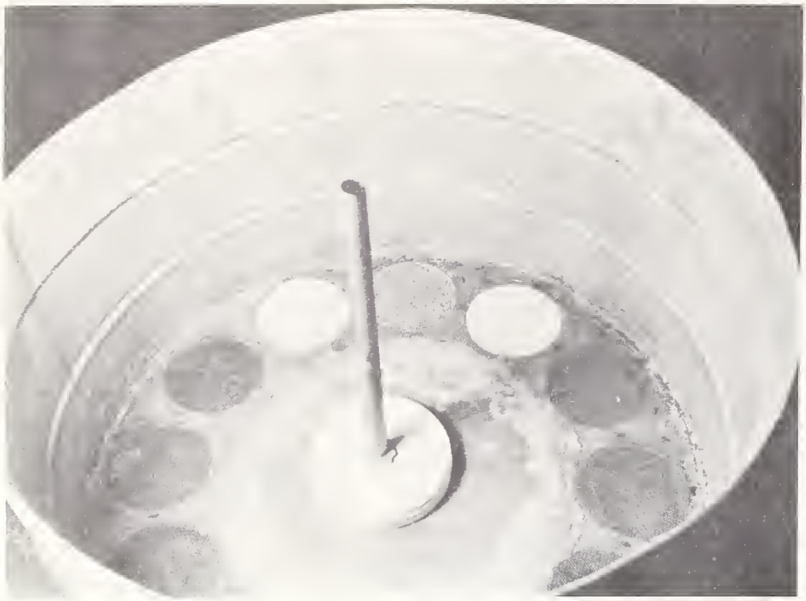

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Figure 5.--Repellency testing apparatus, showing sample cups in place, and tube by which insects were introduced.

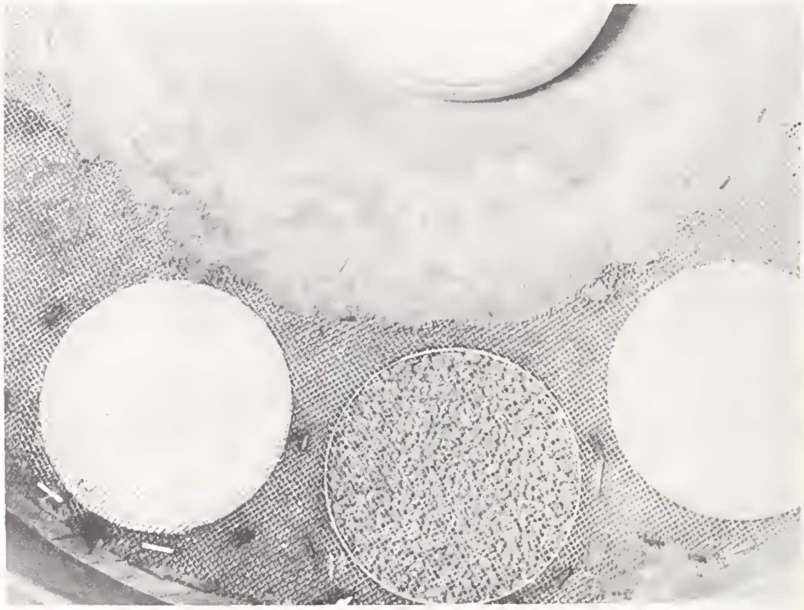

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Figure 6.--Closeup of screen-covered cups in Repellency testing apparatus.

The number of insect-damaged kernels was recorded for samples of corn before treatment and immediately after, 1 month after, and every 3 months after treatment. One hundred kernels from each of 10 probe samples were examined visually for exit holes or other evidence of insect chewing. The total number was recorded as "insect damage per 1,000 kernels" from each bin.

In addition to the visual examinations, insect damage was estimated from X-ray analyses of a representative 500-kernel sample from each bin. These samples were sent to the Stored-Product Insects Research and Development Laboratory at Savannah, Ga. A General Electric Grain Inspection X-ray analysis unit was used. The damaged kernels were classified into three categories: those with external damage only; those with internal damage only; and those having both types of damage.

Immediately after treatment and at monthly intervals thereafter, 400-gram samples of corn were taken from the composited probe samples from each of the malathion-treated bins, sealed in 1-quart jars, and immediately placed in cold storage at 0° F. These samples were

TABLE 2.--Summary of average temperature of shelled corn in bins treated with inert dust and malathion, Tifton, Ga., December 1963 - September 1964

Date	Temperature of corn treated with--					
	Perma-Guard	Kenite	Dri-Die SG-68	Cab-O-Sil M-5	Malathion	No treatment
	°F.	°F.	°F.	°F.	°F.	°F.
1963:						
December	56.4	56.2	52.8	55.8	53.2	57.0
1964:						
January	52.0	58.0	59.8	59.4	60.2	61.0
February	59.8	61.4	57.0	59.2	59.2	67.6
March	63.4	70.0	65.0	61.8	70.6	74.2
April	79.0	76.0	72.0	75.8	70.2	90.0
May	80.4	82.4	84.4	83.0	84.0	94.6
June[1]	88.6	92.4	88.6	91.4	92.2	102.2
June[2]	88.8	98.5	89.1	90.6	87.9	102.3
July	84.6	87.9	85.3	85.7	82.8	92.5
August	92.1	88.9	90.7	92.7	85.9	97.8
September	78.3	78.9	78.2	80.5	76.4	85.2

[1] Readings through June 1964 were made with bin thermometer.

[2] Readings in June 1964 and after were made with potentiometer. Values are average of 3 depths in bins.

then sent to the Stored-Product Insects Research and Development Laboratory at Savannah, Ga., for chemical analyses of malathion residue. A few samples of untreated corn were also analyzed. The analytical method used for the determination of malathion residue is described in the Stored-Product Insects Research Branch Manual of Methods, Pr 1e-61.[5]

EXPERIMENTAL RESULTS

Temperature and Moisture Content of Corn

The corn temperature, recorded in each bin at monthly intervals, was fairly uniform within the replications of each treatment. Therefore, only the average temperature of the five bins is given (table 2). Temperatures read by the bin thermometer and by the potentiometer in the same bins in June were very similar, except in the group of Kenite-treated corn bins. No explanation can be given for the higher temperature readings with the potentiometer. In July, the temperature decreased to a lower level that was more in line with the temperature in some of the other bins.

The average corn temperature decreased from the 80° to 85° F. recorded at the time of treatment to a range of 52.8° to 57.0° by December 1963. The lowest level recorded for the storage year in any of the five replicated treatments was 52.0°. No temperatures low enough to be critical to insect development were recorded. Temperatures increased in most of the bins during January, and by February, had increased several degrees.

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[5] Available from the Stored-Product Insects Research Branch, MQRD, ARS, U.S. Department of Agriculture, Federal Center Building, Hyattsville, Maryland 20782.

TABLE 3.--Summary of average moisture content of shelled corn in bins and treated with inert dust and malathion, Tifton, Ga., September 1963 - September 1964

Date	Moisture content of corn treated with--					
	Perma-Guard	Kenite	Dri-Die SG-68	Cab-O-Sil M-5	Malathion	No treatment
	Percent	Percent	Percent	Percent	Percent	Percent
1963:						
September[1].....	13.1	13.2	12.7	12.7	13.0	12.8
September......	12.1	11.7	11.8	11.8	12.7	12.6
October........	12.2	11.9	12.1	12.0	12.9	12.6
November[2].....	12.0	11.5	11.8	11.8	12.6	12.4
December[3]......	13.3	12.9	13.0	13.1	13.6	13.5
1964:						
January........	13.5	13.0	13.2	13.3	13.8	13.7
February.......	13.4	12.8	13.1	13.1	13.6	13.2
March..........	13.3	12.9	13.1	13.0	13.6	12.6
April..........	13.3	12.8	13.1	13.1	13.8	12.3
May............	13.2	12.8	13.0	13.1	13.7	12.3
June...........	13.3	12.8	13.0	13.0	13.6	12.2
July...........	13.2	12.8	13.1	13.0	13.9	12.0
August.........	13.2	12.9	13.1	12.9	13.7	12.0
September......	12.8	12.6	12.7	12.5	13.6	11.4

[1] Grain samples obtained from receiving trucks before treatment with inert dust or malathion.

[2] Readings through November 1963 made with a Steinlite moisture meter.

[3] Readings in and after December 1963 made with a Motomco moisture meter.

During the latter part of June, some of the bins were quite warm. At this time, the temperature setting on the aeration controls was changed to 75° F., but the relative humidity control was left at 65 percent. During July, the corn was aerated 298 hours. Most of this aeration occurred at night, and the average corn temperature was lowered several degrees. There was no evidence that aeration affected the overall moisture content of the corn.

On July 31, the temperature control was reset to 70° F. and left at that setting through September. During August, the corn was aerated only two nights. During September, the corn was aerated 162 hours, mostly during the cooler nights.

Corn temperature was high in the untreated check bins throughout the summer. The high temperature was a direct result of unusually high insect populations in these bins.

Data recorded in table 2 show that aeration during July lowered the average corn temperature 4° to 10° F. Corn temperature increased again in August, however, because of warmer summer temperatures and fewer hours of aeration.

The summary of data on the average moisture content of corn, by treatment, is shown in table 3. During the cool winter months, moisture content in the upper 5 feet of corn in each bin was higher than that in the lower 5 feet. The reverse was true during the hot summer months. These variations in moisture had little effect on the average moisture of the corn mass. Moisture readings of all corn immediately after treatment with inert dust were lower than before treatment (table 3). The apparent loss in moisture probably resulted from the same factors that lowered the test weight of the corn. The dust-coated kernels did not fall into the moisture cup with the same rate of compaction as the untreated kernels.

Commercial Grades

Commercial grades of the bin samples and the factors upon which grades were based, as determined by an official Federal grain inspector, are averaged in table 4. Grades on samples submitted before and after treatment ranged from No. 1 to No. 4. Corn in most of the bins graded No. 2, but a few more bins graded No. 1 before treatment than after treatment.

Grades varied considerably between corn samples taken before and immediately after treatment. Part of this can be attributed to sample variation. The "before treatment" samples were probed from several trucks, and "after treatment" samples were drawn from bins. After treatment with inert dust, the corn was very difficult to probe; therefore, samples taken after treatment were not so uniform as those taken before treatment. The dust-treated corn was not free-flowing, and the compartments in the probe would not fill uniformly.

The amount of foreign material in the corn and total damage to the kernels also varied. The total damage, more than any of the other factors listed in table 4, greatly influenced the downgrading of the corn 12 months after treatment. In this category, the defects considered were kernels and pieces of kernels of corn that were heat damaged, insect damaged, sprouted, frosted, badly ground damaged, badly weather damaged, moldy, diseased, or otherwise materially damaged.

One important difference in a grade factor of samples taken before and after treatment was in test weight per bushel. The test weight of corn treated with the diatomaceous earth was lowered an average of 3.7 pounds per bushel. The silica aerogel dust reduced test weight an average of 2.6 pounds per bushel. The test weight of malathion-treated and untreated check corn remained about the same after treatment as before.

Twelve months after treatment, insect damage had reduced the average test weight of the untreated check corn 1.8 pounds per bushel. By that time, corn in all of the untreated check bins was designated "sample grade." The percentage of total damage to the kernels was high; the odor was classed as "musty." After 1 year in storage, the test weight of all treated corn was about the same as immediately after treatment. In this same period, there was an increase in total kernel damage, including insect damage.

Malathion Residue

Residue analyses on samples of the malathion-treated corn, taken immediately after treatment, averaged 9.9 p.p.m. (parts per million). One month later, the average malathion residue was 6.8 p.p.m. Residues analyzed on samples varied somewhat from month to month. However, residues were generally reduced at each monthly sampling; and 1 year after treatment, the average was 2.9 p.p.m. The most rapid rate of reduction occurred at the beginning of storage, when residues were high.

In November and July, a few samples of corn from the untreated bins were analyzed for malathion residue. All showed less than 0.5 p.p.m.

TABLE 4.--Average commercial grades and related factors determined on shelled corn in inert dust experiment, Tifton, Ga., September 1963 - September 1964

Treatment	Commercial grade	Test weight	Moisture content	Odor	Heat damage	Insect damage	Total damage	Foreign material	Live insects
	Number	Lb./bu.	Percent		Percent	Percent	Percent	Percent	Number
Perma-Guard:									
Before treatment.........	1.6	57.6	14.0	OK	0	0	3.3	1.3	0
After treatment..........	2.6	53.8	13.7	OK	0	0	4.4	3.2	0
12 months after..........	2.2	54.3	12.5	OK	0.08	0.52	4.7	2.1	0.4
Kenite:									
Before treatment.........	1.6	57.7	13.5	OK	0	.36	3.3	1.9	0
After treatment..........	3.4	54.1	13.0	OK	0	.2	3.4	3.9	0
12 months after..........	2.2	54.4	12.4	OK	0	.48	4.2	2.4	.2
Dri-Die SG-68:									
Before treatment.........	2.0	57.0	13.7	OK	0	.2	4.5	2.0	.4
After treatment..........	2.6	54.5	13.1	OK	0	.28	4.0	2.8	.4
12 months after..........	2.6	54.5	12.6	OK	(1)	.58	5.0	2.0	0
Cab-O-Sil M-5:									
Before treatment.........	1.2	57.0	13.6	OK	0	0	2.9	2.0	.2
After treatment..........	2.4	54.3	13.2	OK	0	0	2.6	2.9	0
12 months after..........	2.0	54.3	12.5	OK	0	.78	3.9	1.9	.2
Malathion:									
Before treatment.........	1.8	57.4	13.9	OK	0	0	3.8	1.6	0
After treatment..........	1.8	57.4	13.9	OK	0	0	4.0	2.4	0
12 months after..........	2.6	57.7	13.3	OK	0	.08	5.5	1.8	0
No treatment:									
Before binning...........	2.8	57.0	13.8	OK	0	0	6.2	1.8	0
After binning............	2.6	57.2	13.7	OK	0	0	5.9	2.4	0
12 months after..........	(2)	55.4	11.4	Musty	0	14.06	29.0	2.5	9.6

[1] Trace.
[2] Sample grade.

TABLE 5.--Summary of average insect damage determined by visual examinations of 1,000 kernels from samples of shelled corn for inert dust experiment, Tifton, Ga., September 1963 - September 1964

Date	Damaged kernels per 1,000 in corn treated with--					
	Perma-Guard	Kenite	Dri-Die SG-68	Cab-O-Sil M-5	Malathion	No treatment
	Number	Number	Number	Number	Number	Number
1963:						
September[1].....	3.0	6.4	4.2	3.4	3.0	5.2
September[2].....	4.8	7.6	6.2	7.4	6.6	7.4
October........	4.0	6.8	6.4	4.8	3.8	9.4
December.......	4.4	8.0	8.8	7.4	4.8	19.2
1964:						
March..........	6.0	9.6	10.6	7.8	8.4	64.4
June...........	4.2	9.0	11.4	7.2	3.8	111.0
September......	15.6	12.0	14.8	20.4	6.8	131.0

[1] Samples from receiving trucks before treatment.
[2] Samples from bins immediately after treatment.

Insect Damage

The average number of insect-damaged kernels, recorded from visual examinations of representative samples of shelled corn, is shown in table 5. All bins of corn had some insect-damaged kernels at the beginning of the experiment. The initial damage ranged from 3.0 to 6.4 kernels per 1,000 before treatment, and from 4.8 to 7.6 kernels immediately after treatment. The higher rating immediately after treatment reflects the number of damaged kernels in the infested corn added at the time of treatment.

During the first 9 months of storage, the number of insect-damaged kernels gradually increased. At the end of 12 months, a marked increase of damaged kernels occurred in all bins of corn treated with inert dust. Corn treated with Cab-O-Sil had the greatest number of damaged kernels--20.4 per 1,000. The next greatest number was found in corn treated with Perma-Guard, followed by that with SG-68 and Kenite. Malathion-treated corn had fewest--6.8. The untreated check corn had a very high proportion of insect-damaged kernels.

Data on the number of insect-damaged kernels, as determined by X-ray analyses of shelled corn samples from the bins, are shown in table 6. External damage was rated high before treatment, as well as throughout the storage period. Between the 6- and 9-month samplings, external damage increased sharply in all corn except that treated with malathion.

Internal damage to the kernels was fairly low in all the samples at the beginning of the experiment. By the end of the ninth month, the increase in internal damage to untreated corn was four times as great as in the dust-treated corn; very little increase occurred in the malathion-treated corn.

Insect Populations

The average numbers of live and dead insects found in the probe samples from each monthly sampling period are summarized in table 7. Live insect infestations in the bins of corn treated with SG-68 and malathion remained at zero, or nearly that, throughout the entire 12 months. Infestations in bins treated with Perma-Guard, Kenite, and Cab-O-Sil remained at a low level through the first 8 months, but steadily increased at each of the next four monthly sampling periods. Using the Official Grain Standards of the United States as a criterion, corn

TABLE 6.--Summary of average insect damage determined by X-ray analyses of 500 kernels from samples of shelled corn for inert dust experiment, Tifton, Ga., September 1963 - June 1964

Date and type of damage	Damaged kernels per 500 in corn treated with--					
	Perma-Guard	Kenite	Dri-Die SG-68	Cab-O-Sil M-5	Malathion	No treatment
	Number	Number	Number	Number	Number	Number
1963:						
September:[1]						
External.....	29.6	35.0	32.2	27.6	28.0	28.8
Internal.....	3.8	5.2	5.2	3.6	2.0	3.2
Both.........	.8	3.0	3.0	2.2	1.2	1.6
Total......	34.2	43.2	40.4	33.4	31.2	33.6
September:[2]						
External.....	27.6	31.2	24.8	32.8	32.0	26.0
Internal.....	1.8	6.2	5.8	5.4	1.2	4.4
Both.........	.6	.6	0	.4	.2	1.4
Total......	30.0	38.0	30.6	38.6	33.4	31.8
October:						
External.....	21.0	23.6	30.4	33.6	24.4	28.6
Internal.....	4.0	6.2	8.2	4.6	4.0	6.0
Both.........	.2	.2	1.0	0	.6	.8
Total......	25.2	30.0	39.6	38.2	29.0	35.4
December:						
External.....	34.6	27.4	42.0	39.6	27.8	52.2
Internal.....	2.8	6.2	9.8	4.8	3.6	22.0
Both.........	1.4	1.6	3.0	1.4	2.0	7.4
Total......	38.8	35.2	54.8	45.8	33.4	81.6
1964:						
March:						
External.....	34.0	41.4	54.4	50.6	70.0	50.0
Internal.....	1.4	7.2	6.0	5.6	2.6	53.4
Both.........	.8	3.4	5.8	5.4	3.4	58.2
Total......	36.2	52.0	66.2	61.6	76.0	161.6
June:						
External.....	60.6	75.4	80.8	55.0	33.6	50.6
Internal.....	6.8	8.4	9.6	9.0	4.6	34.2
Both.........	5.0	5.4	5.6	4.0	4.6	83.6
Total......	72.4	89.2	96.0	68.0	42.8	168.4

[1] Before treatment.

[2] After treatment.

TABLE 7.--Summary of average number of insects per 1,000 grams of shelled corn in probe samples from inert dust experiment, Tifton, Ga., September 1963 - September 1964

Date	Insects in corn treated with--											
	Perma-Guard		Kenite		Dri-Die SG-68		Cab-O-Sil M-5		Malathion		No treatment	
	Live	Dead	Live	Dead	Live	Dead	Live	Dead	Live	Dead	Live	Dead
	Number	Number	Number	Number	Number	Number	Number	Number	Number	Number	Number	Number
1963:												
September[1]	0	0.2	0.6	2.2	0.6	1.0	0	0.4	0	0.6	0	0.4
September	0.1	.3	1.8	.4	.06	1.7	0.1	.8	0	1.8	0.8	.6
October	.5	.06	.2	.1	.3	1.3	.2	.5	0.04	1.3	2.7	.08
November	.2	.5	.5	1.0	.4	4.8	.7	1.6	0	2.7	8.4	.9
December	.2	.4		0	0	2.6	.4	1.3	0	2.3	22.8	3.0
1964:												
January	.1	.2	0	.06	0	1.8	.1	1.2	0	2.4	47.0	14.6
February	.06	.06	0	.1	0	1.9	.06	1.1	0	2.5	51.9	17.9
March	.06	.2	0	.3	0	3.9	0	.7	0	2.9	51.2	19.5
April		.3	.06	1.1	.06	3.9	.06	1.4	0	3.3	56.5	20.7
May	.2	.3	.1	.7	0	4.2	.06	1.5	.2	3.5	39.0	26.6
June	.6	.7	.2	2.5	0	4.8	.2	2.6	.8	4.8	72.2	16.4
July	1.5	2.0	.3	.6	0	4.1	.2	1.5	.3	5.1	85.5	28.8
August	3.1	3.3	1.7	1.7	.1	5.8	1.0	2.6	.2	6.1	18.2	32.9
September	4.0	4.4	1.9	1.0	.1	6.6	5.0	5.3	0	7.1	54.8	41.6

[1] Grain samples obtained from receiving trucks before treatment.

would have graded "weevily" in one bin treated with Perma-Guard at the end of 11 months and in two others at the 12-month period. Corn in one of the bins treated with Cab-O-Sil would also have graded "weevily" at 12 months. Numbers of insects recorded in samples examined by the official Federal grain inspector (table 4) differ considerably from the numbers found in samples at Tifton. Part of this difference may have resulted from samples being shipped by parcel post to Kansas City and the elapse of several days before examination. The Tifton samples were retained in glass jars until they were examined. Insects in the bins of untreated corn continued to multiply during the entire test period. All of this corn would have graded "weevily" by the end of 2 months. After 10 months, the corn became so heavily damaged that it would not support an active infestation of rice weevils, and there was a gradual succession of insects from weevils to bran beetles.

In August, air temperatures in the bins during the day averaged more than 110° F. at the surface of the corn. It is not known how this may have affected either the treatments or insect development. A reduction was recorded in the number of live insects in corn from the untreated check bins, and an increase in insects in corn that had been treated with diatomaceous earth.

Insect Emergence

A summary of the average number of insect progeny emerging from samples of corn taken from the bins is shown in table 8. Probe samples drawn immediately after treatment showed a high rate of insect emergence. The number of progeny from treated corn samples gradually decreased during the next two monthly sampling periods and continued at a low rate until the following July. The increase of emergence in July and thereafter agrees with the increase in number of living insects found in the different treatments shown in table 7. In September, 12 months after treatment, samples of corn treated with Perma-Guard had the greatest number of progeny, followed, in order of decreasing numbers of insects emerging, by corn treated with Cab-O-Sil, Kenite, and SG-68.

No insects emerged from the malathion-treated corn samples after the first month, indicating that invading insects were unable to establish themselves in this corn.

In the untreated check corn, insect emergence reached its peak during January. After that, emergence gradually declined until this corn became so heavily damaged that it would not support weevil activity.

Insect Mortality

Results of laboratory bioassay experiments in which the toxicity of inert dusts to several stored-grain insects was determined at various periods after treatment are shown in table 9.

With one exception, at 9 months, Kenite produced higher rice weevil mortalities at all samplings than the other three inert dusts. Cab-O-Sil was the least effective of all the dusts. SG-68, applied at the same rate as Cab-O-Sil, produced higher mortalities throughout the first year's storage. The average rice weevil mortalities on corn treated with SG-68 were very similar to those on corn treated with Perma-Guard and Kenite, even though only one-seventh as much SG-68 was applied.

No explanation can be given for the low rice weevil mortalities produced by all four inert dusts at 6 months after treatment. Malathion, used as the standard treated check, produced 100-percent mortalities until the 12th month after treatment. It was more effective than any of the inert dust materials in controlling rice weevils. The average mortalities of rice weevils exposed to untreated corn at 1 and 3 months were 27.1 and 13.1 percent, respectively. At the other periods, mortality was less than 6 percent.

TABLE 8.--Summary of average number of insects emerging per 1,000 grams of shelled corn from probe samples in inert-dust experiment, Tifton, Ga., September 1963 - September 1964

Date	Insects emerging from corn treated with--					
	Perma-Guard	Kenite	Dri-Die SG-68	Cab-O-Sil M-5	Malathion	No treatment
	Number	Number	Number	Number	Number	Number
1963:						
September......	4.2	1.8	3.6	2.4	1.2	10.8
October........	0	7.2	.6	2.4	0	13.2
November.......	.6	2.4	1.2	.6	0	48.6
December.......	1.8	.6	1.2	1.2	0	143.4
1964:						
January........	0	0	0	1.2	0	305.4
Febraury.......	.6	0	1.2	1.2	0	244.2
March..........	.6	0	0	0	0	240.6
April..........	.6	.6	.6	0	0	206.4
May............	0	0	0	0	0	151.2
June...........	0	1.2	.6	0	0	46.2
July...........	2.4	1.8	0	.6	0	69.0
August.........	5.4	3.0	0	1.8	0	59.4
September......	21.0	1.8	1.2	10.2	0	53.4

TABLE 9.--Summary of average mortality of 4-week-old adult insects exposed for 21 days to shelled corn in inert-dust experiment, Tifton, Ga., October 1963 - September 1964

Insect and months after treatment	Percentage mortality of insects´exposed to corn treated with--					
	Perma-Guard	Kenite	Dri-Die SG-68	Cab-O-Sil M-5	Malathion	No treatment
	Percent	Percent	Percent	Percent	Percent	Percent
Rice weevil:						
1.............	93.3	98.0	85.4	54.8	100.0	27.1
3.............	95.6	97.2	92.4	64.8	100.0	13.1
6.............	77.9	88.4	79.2	34.3	100.0	1.9
9.............	99.2	98.4	95.2	44.8	100.0	5.2
12.............	71.7	95.7	70.2	31.3	97.2	5.1
Confused flour beetle:						
1.............	20.6	43.2	31.2	14.1	98.0	.8
3.............	30.1	37.6	29.3	11.3	88.4	1.2
6.............	21.1	40.4	31.6	23.8	81.8	1.9
9.............	18.0	23.7	47.6	6.0	15.3	1.6
12.............	1.6	9.2	7.2	1.2	3.6	.8
Red flour beetle:						
1.............	--	--	--	--	--	--
3.............	67.2	86.3	48.8	13.3	100.0	.8
6.............	36.9	79.8	59.8	27.5	100.0	1.6
9.............	41.4	75.9	64.4	8.8	83.2	1.2
12.............	5.2	37.2	21.8	2.3	24.0	1.6

In this test, the confused flour beetles were more difficult to kill than rice weevils. One month after treatment, average mortalities of confused flour beetles on all dust treatments ranged from 14.1 to 43.2 percent, while malathion-treated corn produced 98-percent mortality. Toxicity decreased as the length of time after treatment increased, and by 12 months after treatment, mortalities of confused flour beetles had reached a very low level.

Because confused flour beetles seemed comparatively resistant to inert dust in bioassays on the first sampling, red flour beetles were included in the subsequent tests. Mortalities of the red flour beetles ranged between those of rice weevils and those of confused flour beetles. Kenite consistently produced higher red flour beetle mortalities than the other inert dusts. SG-68, even at the lower application rate, was more effective than Perma-Guard, except at the third month. In 12 months, all treatments had decreased in effectiveness.

Average mortalities of confused flour beetles and red flour beetles in untreated samples of corn were never greater than 2 percent.

Insect Reproduction

In another series of bioassays, adult insects were added to samples of corn. The same insects were used in these progeny tests as in the bioassays previously described. As in the other tests, red flour beetles were included in the experiment at the 3-month sampling. Adult insects were confined on the corn for 21 days and were then removed. After an incubation period of 42 days, the number of progeny that had emerged in the meantime, and the percentage of these progeny that had died after emerging were recorded (table 10).

Another phase of the study was to determine if newly emerged weevils would be able to mate, lay eggs, and produce offspring. Rice weevil larvae were reared in untreated corn until 3½ weeks old. Fifteen grams of this infested corn was mixed with samples from each treatment. After 56 days, the insects that had emerged from the corn samples, and any progeny produced, were counted and their mortality recorded.

Compared with no treatment, all treatments reduced considerably the number of progeny of all insects that could develop in the corn (table 10). Malathion inhibited reproduction of the rice weevils, confused flour beetles, and red flour beetles better than any of the inert dust treatments. However, against rice weevil larvae, indications are that none of the treatments prevented development of the established infestation, but there was a definite reduction in number of progeny produced when compared with those produced in untreated check corn. Mortality of the emerging rice weevils was high in malathion-treated corn throughout the 12-month period. Diatomaceous earth, while less effective than malathion, was better than silica aerogel.

There were fewer numbers of rice weevil progeny, as well as higher mortalities among progeny, on Kenite-treated corn than on corn treated with the other three inert dusts (table 10). Malathion provided better progeny control than any of the inert dusts until the 12th month of storage. At that time, progeny in the malathion-treated corn developed in numbers similar to those in some of the inert dust treatments.

The number of progeny of confused and red flour beetles varied in the inert dust-treated samples from one month to the next. In general, however, the number of progeny increased as the length of storage after treatment increased for each of the inert dusts. With the exception of malathion, SG-68 was the most effective treatment in preventing development of flour beetle progeny. None of the treatments produced high mortality of adult insects, but all of them were very efficient in inhibiting progeny development when compared with those developing in the untreated corn.

TABLE 10.--Summary of average number of insect progeny that emerged and percentage that died in shelled corn exposed to insects for stated time in inert dust experiment, Tifton, Ga., October 1963 - September 1964

Insect and months after treatment	Mortality of insect progeny exposed to corn treated with--											
	Perma-Guard		Kenite		Dri-Die SG-68		Cab-O-Sil M-5		Malathion		No treatment	
	Emerged	Died	Emerged	Died	Emerged	Died	Emerged	Died	Emerged	Died	Emerged	Died
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Rice weevil:[1]												
1	22.8	19.3	13.6	23.5	32.6	6.1	73.2	3.6	0.2	100.0	306.6	6.3
3	20.4	67.6	22.4	66.1	28.0	25.0	52.6	5.3	.6	66.7	384.2	6.9
6	46.2	14.7	20.4	35.3	53.8	3.0	102.2	.8	.6	100.0	310.2	2.3
9	18.0	50.0	18.8	36.2	15.2	26.3	71.8	3.1	6.0	80.0	287.6	4.4
12	46.2	8.2	27.8	25.2	31.4	13.4	100.0	1.8	35.4	46.9	311.0	2.1
Confused flour beetle:[1]												
1	2.6	23.1	2.0	40.0	2.4	33.3	2.8	14.3	0	--	25.8	3.1
3	3.0	26.7	3.6	11.1	3.0	20.0	7.4	13.5	0	--	10.8	1.9
6	1.0	0	0	--	0	--	5.0	0	0	--	91.0	20.0
9	3.4	11.8	6.4	0	0	--	5.2	3.8	.2	0	93.2	.2
12	13.4	0	6.0	0	1.0	20.0	18.2	0	.2	0	157.8	.1
Red flour beetle:[1]												
1	--	--	--	--	--	--	--	--	--	--	--	--
3	2.0	0	.6	0	0.4	0	1.4	28.6	0	--	44.4	0
6	2.8	21.4	2.6	15.4	0	--	2.8	7.1	0	--	84.8	2.4
9	2.2	0	4.0	20.0	.6	0	8.4	9.5	.2	0	85.8	1.2
12	10.0	4.0	2.8	14.3	2.8	7.1	22.8	.9	0	--	254.4	.6
Rice weevil larva:[2]												
1	28.8	83.3	25.0	84.0	27.0	63.7	33.6	30.4	22.2	97.3	107.0	7.9
3	51.0	85.1	50.8	93.3	45.2	30.1	49.0	21.6	43.8	99.5	183.8	10.0
6	48.4	82.6	45.6	92.1	45.8	16.2	60.4	5.6	46.4	100.0	130.2	4.9
9	39.0	90.4	41.6	94.7	50.6	64.4	46.4	20.3	43.2	99.5	58.2	8.6
12	42.4	83.0	44.6	92.4	45.0	34.2	67.8	2.7	41.6	91.3	89.0	3.4

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[1] Counts made 42 days after exposing adult insects to corn for 21 days, then removing adults.

[2] Counts made 56 days after mixing infested corn with treated corn samples.

Repellency of Treatments

Repellency of the several treatments to insects, according to bioassays, is shown in table 11. Compared with untreated corn, corn treated with inert dust was highly repellent to rice weevils. Diatomaceous earth gave higher percentages of repellency than silica aerogel. Kenite had greater repellency than Perma-Guard at all test dates except the first month. The percentage of repellency decreased for all dust, with the exception of SG-68, as the storage period progressed. Repellency of SG-68 increased from the third to the ninth month and decreased at 12 months.

The degree of repellency shown in the laboratory tests agreed well with the numbers of insects found in probe samples taken directly from the treated bins (table 7). As repellency of the inert dust decreased, numbers of living insects increased. The repellency of Kenite remained at a high level throughout the 12 months, and very few live insects were found in the Kenite-treated corn.

The malathion-treated samples showed repellency at all dates, except 12 months after treatment. The percentage of repellency also showed a decrease at 9 months. As evidenced by the small numbers of living insects in the malathion-treated corn from the 6- to 12-month samplings, even though the repellency decreased, the toxicant effectively restricted the potential for insect increase to a low level.

TABLE 11.--Summary of repellency of treated shelled corn to rice weevils in inert-dust experiment, Tifton, Ga., October 1963 - September 1964

Months after treatment	Percentage repellency of corn treated with--				
	Perma-Guard	Kenite	Dri-Die SG-68	Cab-O-Sil M-5	Malathion
	Percent	Percent	Percent	Percent	Percent
1	93.0	90.2	63.0	68.0	58.8
3	78.2	87.4	82.0	71.2	60.8
6	81.2	86.0	73.4	67.6	45.0
9	74.8	88.8	80.6	40.0	14.4
12	36.0	82.4	60.0	5.2	-33.8

FINDINGS

Although the experiment with inert dust as a protective treatment has not been completed, the following points were evident at the end of the first year of the experiment:

1. The overall moisture content of the corn changed little during this year, except in the untreated check corn.

2. Inert dust treatments cost from 17 to 30 times as much as the standard malathion treatment.

3. The dust treatments reduced the loading capacity of the grain conveyor to one-half the amount of the untreated or malathion-treated shelled corn.

4. The corn was very difficult to probe as a result of the inert dust treatments; therefore, samples taken after treatment were not as uniform as those taken before treatment.

5. The test weight of shelled corn treated with diatomaceous earth dust was lowered an average of more than 3.5 pounds per bushel. Silica aerogel dust reduced test weight an average of 2.6 pounds per bushel. After treatment with either dust, the grade of corn was lower.

6. The live insect infestation present at the time of treatment had decreased to a low level by the end of the third month after treatment. According to Commercial Grain Standards, the

untreated check corn graded "weevily" at the second month of storage. The corn in three bins treated with Perma-Guard and one with Cab-O-Sil became weevily in 12 months. The corn treated with Kenite, Dri-Die SG-68, or malathion did not become "weevily."

7. All treatments were effective through 8 months of storage. After this time, numbers of live insects, development and emergence of internal infestation, and insect-damaged kernels increased in corn treated with Perma-Guard, Kenite, and Cab-O-Sil M-5.

8. Corn treated with inert dust was highly repellent to rice weevils, when compared to untreated corn.

9. In laboratory bioassay tests, malathion was more effective over a longer period of time against adults of the rice weevil, confused flour beetle, and the red flour beetle than any of the inert dusts. Perma-Guard, Kenite, and Dri-Die SG-68 were only slightly less effective than malathion against the rice weevil, but overall progeny development was greater in the dust-treated corn.

10. At the end of 12 months' storage, malathion was superior to all dusts in all factors evaluated, except as a repellent. Next in order of effectiveness as overall protectants were Kenite and Dri-Die SG-68, followed by Perma-Guard and Cab-O-Sil M-5.

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